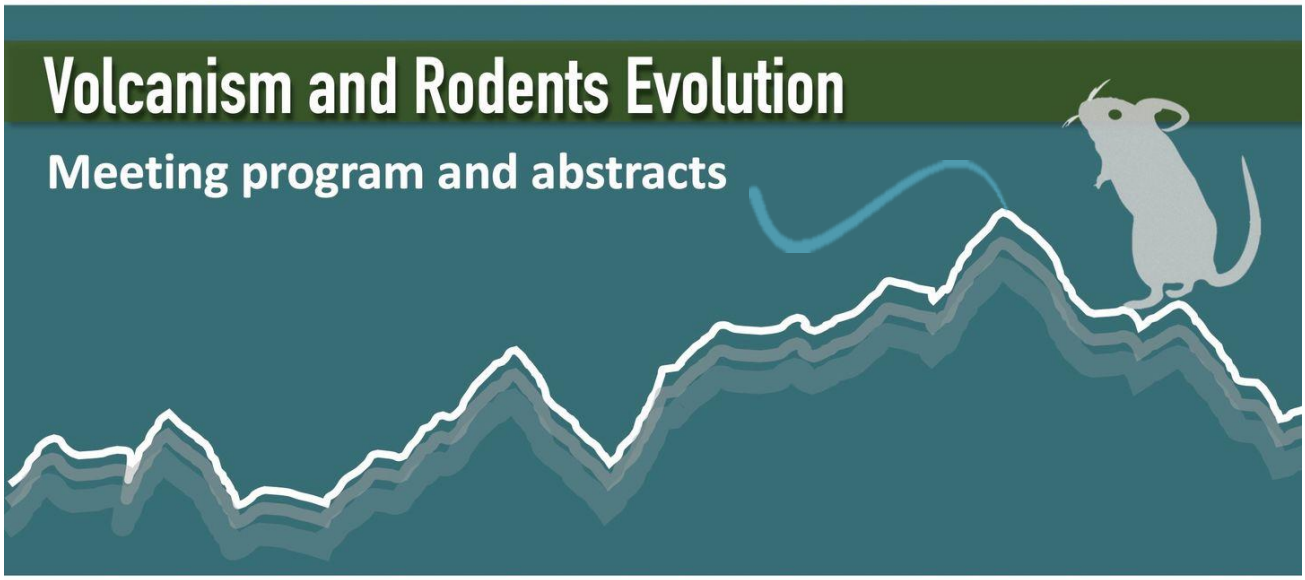
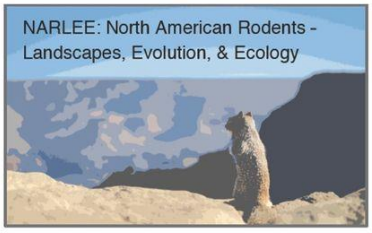

# Volcanism and Rodents Evolution

## Meeting program and abstracts





## Organizers:

**Joaquín Arroyo-Cabrales**
*(Instituto Nacional de Antropología e Historia)*

**Adolfo Pacheco-Castro**
*(Universidad Nacional Autónoma de México)*

**Samantha Hopkins**
*(University of Oregon)*

**David Fox**
*(University of Minnesota)*

**Virtual mode in Zoom**
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# RCN Mammal Diversification in Relation to Dynamic Landscapes
# NARLEE Workshop of Volcanism and Rodents Evolution
# 16-17 November 2021

## Introduction

Terrestrial vertebrates show striking changes in species richness across topographic gradients. For mammals, nearly twice as many species per unit area occur in topographically complex regions as in adjacent lowlands. The geological context of this pervasive biogeographic pattern suggests that tectonic processes have a first-order impact on regional diversity. The project titled **Mammal Diversification in Relation to Dynamic Landscapes** focuses on studying fossil evidence of small-mammal evolution from the Miocene to the Pleistocene, and evaluating how topographic and landscape changes could be influencing that evolution. The goal of this collaborative research is to elucidate how speciation, extinction, geographic range shifts, and environmental sorting have shaped the diversity of mammals in topographically complex regions in the context of dynamic landscape history. Network participants represent a diverse range of expertise in biodiversity and earth sciences.

The goal of this workshop is to discuss the importance of rodent evolution in regions with volcanic activity. On the first day, we will discuss the principal geologic aspects relevant to understand the evolution of the volcanic provinces in North America during the Neogene, with particular attention in Mexico and southwestern USA. On the second day, we will talk about the particularities of the ecosystems in volcanic provinces, focus on the diversity of rodents in a geologically active landscape, and discuss the processes and evolutionary patterns observable in rodent faunas and fossils.

This workshop will occur over two consecutive days for four hours each day, from 10 am to 2 pm Central Standard Time (CST; please adjust for your time zone). We will have a 20-minute break after the second hour. Two daily sessions, each with three 20-minute presentations and 10 minutes for specific discussions, and a final discussion each day with 20 minutes round table conversations in small groups and 20 minutes for general discussion.

## Schedule for Day 1 (November 16th)

Central Standard Time (CST)

**Topics**: The origin and geologic dynamics of volcanic provinces in the southern USA and north-central Mexico. What volcanic processes can influence the evolution of ecosystems, mammalian faunas, and rodents?

Introduction and moderator — Joaquin Arroyo-Cabrales; notetaker—David Fox

| Time | Activity |
|---|---|
| 10:00 | Welcome and review of schedule (Catherine and Joaquin); introductions of participants. Goals for today's presentations and discussion |
| 10:15 | Luca Ferrari — Geologic evolution of the Trans-Mexican Volcanic Belt and its bearing on the biological evolution. |
| 10:35 | Q&A, discussion |
| 10:45 | Christopher D. Henry — The late Cenozoic magmatic smorgasboard of western North America: distribution, timing, composition, relative volumes, and tectonic setting |
| 11:05 | Q&A, discussion |
| 11:15 | Jon J. Smith — Volcanic ash bed chronostratigraphy in Cenozoic deposits of the Great Plains, North America |
| 11:35 | Q&A, discussion |
| 11:45 | Break |
| 12:05 | Mark Clementz — Rising from the ashes: linking Andean volcanism, diatoms, and marine mammal diversity with the late Miocene Cooling Event |

12:25 Q&A, discussion

12:35 Ana Lillian Martin-Del Pozzo — Recent Impact of volcanic ash in central Mexico

12:55 Q&A, discussion

13:05 Richard H. Madden — Pyroclastic sediments in rodent tooth shape evolution?

13:25 Q&A, discussion

13:35 Discussion in groups: At least 3 teams, each one discusses for 20 minutes about What kinds of phenomena affect the evolution of rodents? Which of these can be observed in the fossil record? What data can be obtained?

13:55 General thoughts of each group to everybody.
What have these new models and results shown?
What hypotheses are we able to test? Can we rule any out?
How do we integrate these different datasets and results?
Looking ahead to tomorrow

14:15 Adjourn

## Schedule for Day 2 (November 17th)

Time CST

**Topics**: The influence of the volcanic activity on ecosystems, with special attention to rodent faunas. Here we will discuss the impact of volcanic activity like ash fall or the landscape structure as sky islands. What kinds of phenomena affect the evolution of rodents? Which of these can be observed in the fossil record? What data can be obtained?

Introduction and moderator—David Fox; notetaker—Joaquin Arroyo-Cabrales

| Time | Activity |
|---|---|
| 10:00 | Welcome and overview of schedule for the day; introductions of new participants; goals for today's presentations and discussion |
| 10:15 | Samantha Hopkins — Role of volcanic activity in the evolution of hypselodonty in aplodontiid rodents |
| 10:35 | Q&A, discussion |
| 10:45 | Alicia Mastretta-Yanes — From genetic to species diversity in the Transmexican Volcanic Belt sky-islands |
| 11:05 | Q&A, discussion |
| 11:15 | Rebecca Rowe — Sky Islands |
| 11:35 | Q&A, discussion |
| 11:45 | Break; leave meeting open for any who want to chat with each other |
| 12:10 | Livia León-Paniagua — Diversity of rodents in Mexico, special attention in central Mexico |
| 12:30 | Q&A, discussion |
| 12:40 | César Ríos-Muñoz — The Transmexican Volcanic Belt Province: its role in the Neartic-Neotropical transition area |

| | |
|---|---|
| 13:00 | Q&A, discussion |
| 13:10 | Final discussion: at least 3 teams, each one discusses for 20 minutes about: what kinds of phenomena affect the evolution of rodents, which of these can be observed in the fossil record? what data can be obtained? |
| 13:30 | Close of the discussion, one representative per team shares with the whole group the main ideas that were discussed.<br>Discussion and future work |
| 14:00 | Adjourn |

**10:15**

## THE TRANS-MEXICAN VOLCANIC BELT AND ITS INFLUENCE ON THE CLIMATE AND BIOLOGICAL EVOLUTION OF CENTRAL MEXICO

Luca Ferrari
*Centro de Geociencias, Universidad Nacional Autónoma de México*

The Trans-Mexican Volcanic Belt (TMVB) is a ~1,000 km long Neogene volcanic province that crosses central Mexico from the mouth of the Gulf of California to the Gulf of Mexico. It has a variable width (80 to 230 km) and a preferential E-W direction in its central and eastern part that changes to WNW-ESE in its western part, forming an angle of ~16 ° with respect to the Middle America Trench. Taking into account the spatial distribution of volcanism and its composition, Ferrari *et al.* (2012) have summarized the geological history of the TMVB in four main episodes that have implications for biological evolution: 1) building of an andesitic volcanic arc in the early to middle Miocene East of Long 101° W; 2) late Miocene pulse of basaltic volcanism forming plateaus north of the previous arc; 3) late Miocene to early Pliocene episode of explosive and effusive silicic eruptions, with initial migration of volcanism toward the south, and 4) re-establishment of an arc with great compositional variability since the late Pliocene characterized by the formation of large stratovolcanoes from the Pleistocene.

Additionally, the TMVB has been affected by an intra-arc extensional tectonics that is particularly evident in its western half, where it has created important E-W trending morphological depressions and lakes since the early Pliocene.

Due to the spatial migration of volcanism, the eruptive style variation, and the development of tectonic basins, the TMVB did not represent a continuous morphological barrier, although it has had an impact on the climate by isolating the Mesa Central to the north from the moisture that comes from the coast of Jalisco, Michoacán and Guerrero. With regard to biological evolution, the TMVB has developed gradually as a plateau fragmented by basins with microclimates that, depending on the type of flora or fauna, can represent either a discontinuous barrier between the north and the south or an irregular communication route in east-west direction. At a local level and for species with little mobility it is evident the influence of the TMVB in the separation of clades that were previously distributed in a wider region from central to southern Mexico from the late Miocene (e.g. Mulcahy *et al.,* 2006; Ruiz-Sanchez and Spech, 2013). In other cases, the TMVB constituted a region of independent evolution with internal vicariant events and irradiation of species, probably associated with the aforementioned episodic geological evolution (e.g. Doadrio *et al.,* 2004; Bryson and Riddle, 2012).

*References:*


- Doadrio, I., & Domínguez, O. (2004). Phylogenetic relationships within the fish family Goodeidae based on cytochrome b sequence data. *Molecular phylogenetics and evolution*, *31*(2), 416-430.
- Bryson R.W., Riddle, B. R. (2012). Tracing the origins of widespread highland species: a case of Neogene diversification across the Mexican sierras in an endemic lizard. *Biological Journal of the Linnean Society*, *105*(2), 382-394.
- Ferrari, L., Orozco-Esquivel, M.T., Manea, V., Manea, M., 2012. The dynamic history of the Trans-Mexican Volcanic Belt and the Mexico subduction zone. *Tectonophysics*, *522–523*, 122–149.
- Mulcahy, D. G., Morrill, B. H., & Mendelson, J. R. (2006). Historical biogeography of lowland species of toads (Bufo) across the Trans-Mexican Neovolcanic Belt and the Isthmus of Tehuantepec. *Journal of Biogeography*,*33*(11), 1889-1904.
- Ruiz-Sanchez, E., y Specht, C. D. (2013). Influence of the geological history of the Trans-Mexican Volcanic Belt on the diversification of Nolina parviflora (Asparagaceae: Nolinoideae). *Journal of Biogeography*, *40*(7), 1336-1347.

**10:45**

## THE LATE CENOZOIC MAGMATIC SMORGASBOARD OF WESTERN NORTH AMERICA: DISTRIBUTION, TIMING, COMPOSITION, RELATIVE VOLUMES, AND TECTONIC SETTING

Christopher D. Henry
*Nevada Bureau of Mines and Geology, University of Nevada*

The late Cenozoic magmatic-tectonic development of western North America is extremely complex and closely tied to the transition from (1) subduction of the Farallon plate beneath North America to (2) collision of the East Pacific Rise and subduction zone and (3) formation of an evolving transform margin between the Pacific and North American plates. The greatest volume of volcanic rocks formed during subduction from rollback (steepening) of the Farallon slab, which had flattened during the Late Cretaceous – early Cenozoic. Rollback magmatism began ~50 Ma in the eastern Cordillera and migrated southwestward, toward the subduction zone, through the Neogene in both southwestern US and northwestern Mexico. Rollback magmatism initially consisted of a mix of voluminous, rhyolitic, caldera-forming eruptions between ~37 and 19 Ma with accompanying intermediate lavas (the ignimbrite flareup) and, closer to the subduction zone, mostly changed to predominantly intermediate stratovolcanoes and dome complexes and a few rhyolitic, caldera-forming eruptions. In the Great Basin and Sierra Nevada, the intermediate activity is the "ancestral Cascades arc".

A slab window began ~30 Ma when the EPR reached the trench, and Mendocino and Rivera triple junctions migrated north and south to their present positions, progressively for the MTJ and in two major jumps at ~18 and 12 Ma for the RTJ. Subduction magmatism shut off as the triple junctions moved and transform system lengthened, but other types of magmatism persisted. The late caldera-forming eruptions generally occurred above the slab window. Middle Miocene initiation of the Yellowstone hotspot in northern Nevada – southeastern Oregon, coeval with rollback and major extension in the Great Basin, generated the voluminous Columbia River Basalts, numerous silicic calderas near the plume head, and the predominantly basaltic northern Nevada rift. In Baja California and Sonora, where extension began as early as ~30 Ma, post-subduction magmatism is largely related to rifting that led to the Gulf of California. Throughout the region, dispersed, small volume, mostly basaltic, intraplate volcanism continues to today.

**11:15**

## VOLCANIC ASH BED CHRONOSTRATIGRAPHY IN CENOZOIC DEPOSITS OF THE GREAT PLAINS, NORTH AMERICA

Jon J. Smith
*Kansas Geological Survey*

Volcanic ash beds are found in Cenozoic deposits of the Great Plains with high stratigraphic frequency, though typically of a very limited geographic extent. Where relatively unaltered, these beds are preserved as airfall tephra composed of fine-grained, micron-scale rhyolitic glass shards sorted by long-distance atmospheric transport. Ash beds are ideal geochronological marker horizons in sedimentary successions because they also often contain radiometric materials, such as zircons, that can provide absolute depositional ages of host sediments in which they occur. Nearly 2,500 individual surficial ash beds are recognized in the Great Plains regions of KS, NE, OK, SD, CO, TX, NM and IA. Paleosol horizons are also common and laterally extensive throughout the Great Plains and are additional likely hosts for concentrations of zircons from contemporaneous volcanic ash falls that are worked into the soil matrix via mixing. Uranium-lead (U-Pb) dates of individual zircon grains are derived via laser ablation inductively coupled mass spectrometry (LA-ICP-MS). The maximum depositional age (MDA) of the host deposit is calculated from youngest population of zircons recovered. MDAs derived from ash beds and paleosols of the Ogallala Formation in Kansas and Nebraska correlate primarily with geologically frequent volcanic super-eruptions associated with the Snake River Plain-Yellowstone hotspot (16.1–0.6 Ma).

**12:05**

## RISING FROM THE ASHES: LINKING ANDEAN VOLCANISM, DIATOMS, AND MARINE MAMMAL DIVERSITY WITH THE LATE MIOCENE COOLING EVENT

Mark Clementz
*Department of Geology and Geophysics, University of Wyoming*

The Late Miocene Cooling event (LMC, 7.6 to 5.4 Ma) marks a short-lived but significant drop in global temperatures that has been noted in marine and terrestrial records, foreshadowing the onset of Plio-Pleistocene bipolar glaciation. The cause of this event is unclear but is thought to be related to a dramatic drop in $CO_2$ that was associated with the establishment of modern cetacean communities (increased abundance of balaenopterids and delphinids, decline of cetotheriids and platanistoids), colonization of the Southern Hemisphere by otariids, and a decline in sirenian diversity. On land, this event is associated with an increase in the global abundance of $C_4$ grasses and expansion of arid conditions in terrestrial environments. Chemical weathering of Ca-silicate rocks remains the primary hypothesis to explain global Cenozoic cooling via $CO_2$ drawdown, with the Himalayas and Tibetan Plateau often identified as the most likely source material. Here, we propose an alternative mountain system, the Andes of western South America, as the site for this process and suggest that enhanced volcanism may have been the trigger for the LMC.

We compiled an exhaustive dataset of >4000 magmatic ages from the Central Andes and identify a significant increase in frequency of volcanic events from 9 to 5 Ma with a peak at 7.0 Ma. The role of volcanism on global climate remains debated but is most often argued to contribute to global warming through $CO_2$ release. However, active Andean volcanism and mountain building in the Late Miocene would also have fertilized marine surface waters with silica and iron, enhancing diatom productivity and intensifying the biological pump, significantly contributing to carbon burial and $CO_2$ drawdown in the Cenozoic. Comparison of volcanic activity in the Central Andes with benthic and planktic isotopic records (d13C, $d^{18}O$), diatom abundance data, and marine sediment chemical alteration indices from deep sea cores show a strong correlation, support a connection between Cenozoic Andean volcanism and major climatic and biotic events at the LMC. We conclude that volcanism is a key driver of climate change and biotic events over geological times through its ability to contribute both positively and negatively to global temperatures.

## 12:35

## RECENT IMPACT OF VOLCANIC ASH IN CENTRAL MEXICO

Ana Lillian Martin del Pozzo
*Instituto de Geofísica, Universidad Nacional Autónoma de México*

Recent vulcanism from both monogenetic and polygenetic volcanoes has frequently produced ash fall over central Mexico since Paricutin was born in the early 40's. After the disaster associated with the Plinian eruption from Chichón volcano in southeastern Mexico, hazard maps for Colima Volcano, Popocatepetl, Citlatepetl, Ceboruco and Chichón, were published. Detailed ash fall scenarios were prepared for Colima volcano that has had frequent eruptions since 1961 and for Popocatepetl that has been active with small Vulcanian and Strombolian eruptions since 1994. Both volcanoes have produced ash fall associated with dome growth and collapse and pyroclastic flows and lahars reaching 4 to 15 km away. The ash fall, on the other hand, has impacted areas up to 100 km away affecting the growth of agave, sugar cane and peaches as well as cattle production in the Colima area and at least walnut production in the Popocatepetl area in central Mexico. Ash emission has also affected human heath at both Colima and Popocatepetl. On the other hand, an increase in the populations of several mammal species such as the coyote (*Canis latrans*) and the endemic volcano rabbit (*Romerolagus diazi*) has been detected in the Popocatepetl National Park, which has been off limits since 1994 because of the eruptions.

**13:05**

## PYROCLASTIC SEDIMENTS IN RODENT TOOTH SHAPE EVOLUTION?

Richard H. Madden
*Department of Organismal Biology and Anatomy, University of Chicago*

The prevalence of hypsodonty among mammals and its association with volcanism (in the broad sense) is now widely recognized. The ecological and evolutionary response to the abrasiveness of pyroclastic sediments can be observed at many temporal and geographic scales. It may characterize small mammals in the Central Plateau of Mexico, as it does in the Altiplano of Peru-Bolivia, the Callejón Interandino of Ecuador, and the Patagonian massif in the Southern Andes. Beyond, it is a feature of the Plio-Pleistocene fossil mammal record in Ethiopia, as well as volcanic islands on the Mediterranean. Accelerated tooth wear observed in modern volcanic settings, on both oceanic and orographic islands, probably sets the stage for what happened in the past. That is, geographic isolation amid topographic complexity of volcanic mountains where surface processes coupled with accelerated weathering and erosion rates deliver pyroclasts onto the foods mammals eat, occurs in settings where there is no escape.

Beyond the description of these coincidences, observational, experimental and quantitative approaches enable a better understanding. Contrasts among feral populations on volcanic and non-volcanic islands are an obvious approach where volumetric and chronometric methods of measuring tooth wear rates can be used. Feeding experiments dosing captive mammal diets with pyroclastic sediments have been conducted and preliminary results have illustrated the 3D microwear fabric. A quantitative approach modeling the evolutionary significance of tooth wear variation would complement and complete our appreciation of this mechanism of tooth shape evolution.

**10:15**

## ROLE OF VOLCANIC ACTIVITY IN THE EVOLUTION OF HYPSELODONTY IN APLODONTIID RODENTS

Samantha Hopkins
*Department of Geological Sciences and Clark Honors College, University of Oregon*

Our understanding of mammalian hypsodonty evolution has changed substantially over the last two decades, with a number of studies demonstrating that the simple story of a correlation between grazing and increasing tooth crown height is only part of the picture. Studies of South American mammals' exceptional hypsodonty led to suggestions of the potential importance of volcanically-produced grit as a driver of crown height evolution. While the effects of volcanism on dental evolution in herbivores of the Cenozoic of South America are clearly profound, the same process may be at work on a smaller scale in volcanically active western region of North America. One clade particularly subject to these volcanic drivers of evolution is the Aplodontiinae, which are limited almost exclusively to the Northwestern U.S. during the middle and late Miocene. While few small mammals have adequate phylogenetic data to enable such consideration, the Aplodontoidea offer an ideal study system, with well-studied ecology, phylogeny, and ecological context. Within this clade, hypsodonty has evolved in parallel twice, once in mylagaulids and once in aplodontiines. Detailed study of the evolution of hypselodonty in aplodontiines shows that the most extreme hypsodonty and eventual hypselodonty evolved in only a single part of the geographic range, in Oregon and Northwest Nevada during the Middle Miocene. Populations from even a small distance to the south, even in dry habitats, were characterized by much smaller degrees of hypsodonty at the same time. The origin of hypselodonty in this lineage, then, seems to have been a response to a relatively local phenomenon, possibly the extensive volcanic activity from the Yellowstone Hotspot and the Columbia River Basalts.

**10:45**

## FROM GENETIC TO SPECIES DIVERSITY IN THE TRANSMEXICAN VOLCANIC BELT SKY-ISLANDS

Alicia Mastretta-Yanes
*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, CONABIO*

Tropical mountains are biodiversity hotspots, not only due to their astonishing array of climatic conditions, but also because historical processes have driven evolution. Tropical sky islands represent a good system to examine evolutionary dynamics of tropical montane regions, because their insular nature allows for explicit hypothesis testing. Specifically, in sky islands an expected consequence of the emergence of new mountains is the promotion of species divergence either after colonization from neighboring highlands (allopatric divergence and niche conservatism) or through the colonization of newly emerged high-elevation habitats from lower elevations within the same mountain (peripatric or parapatric divergence and niche shift). In addition to isolation, coupling altitudinal gradients with tropical latitudes allows populations within tropical mountains to persist relatively *in situ* despite global climate fluctuations. These processes of isolation and long-term *in situ* persistence have been widely used to explain diversification among tropical mountain peaks. However, we show that dispersal limitation within a single mountain could also play an important role in generating endemism.

**11:15**

## SKY ISLANDS

Rebecca Rowe
*Department of Natural Resources and the Environment, University of New Hampshire*

Understanding variation in the number of species has been a central aim of ecology. Mountains provide an excellent system for addressing this question because elevation covaries with geophysical, environmental, and physiographic factors that influence fundamental processes which structure the position, extent, and overlap of species ranges, and thus geographic variation in biodiversity. In addition, the numerous mountain systems worldwide provide the opportunity for comparative studies to test for generality of pattern and process. Most elevational diversity studies have documented either a unimodal (or hump-shaped) relationship with richness greatest at mid-elevation or a decrease (often monotonic) in richness with increasing elevation. Despite the generality of patterns, much debate remains around the underlying causes with a variety of environmental and spatial factors receiving frequent support. Focusing on small mammals (rodents and shrews) in the Intermountain West of North America, I provide an overview on elevational diversity gradients, including both the patterns perceived and the underlying mechanisms identified.

**12:10**

## DIVERSITY OF RODENTS IN MEXICO, SPECIAL ATTENTION IN CENTRAL MEXICO

Livia León-Paniagua
*Departamento de Biología Evolutiva, Facultad de Ciencias,*
*Universidad Nacional Autónoma de México*

The geographic distribution and richness of rodents in central Mexico, as well as the high endemism, has responded, among other things, to the geology of the Transmexican Volcanic Belt. The four episodes of volcanism during 19 Ma have facilitated the presence of about 70 rodent species, distributed in 26 genera, with 11 species endemics to the Transmexican Volcanic Belt. Today there are 13 genera endemic to Mexico, 12 of which are found in central Mexico. The family Cricetidae is the most diverse within the Transmexican Volcanic Belt; however, squirrels (Sciuridae), gophers (Geomyidae) and chewing rodents (Heteromyidae) are well represented in central Mexico. The confluence of the Nearctic and Neotropical regions, the characteristic topography of mountains and valleys, semi-dry to humid forests, and the biogeographic origin of the eastern and western Transmexican Volcanic Belt have operated as an "incubator" for rodent species.

**12:40**

## THE TRANSMEXICAN VOLCANIC BELT PROVINCE: ITS ROLE IN THE NEARTIC-NEOTROPICAL TRANSITION AREA

César Ríos-Muñoz
*Centro de Estudios Mexicanos UNAM-Costa Rica,*
*Universidad Nacional Autónoma de México*

The position of Mexico, located between the Nearctic and the Neotropics, has represented a challenge in the biogeographic understanding, due to the lack of conspicuous barriers that represent evident geographic limits between both regions. This limit represents a gradual change, associated mainly with the mountain zones in the country. The entire area has been named *the Mexican Transition zone* by some authors, and the Transmexican Volcanic Belt province is part of it. This province has been characterized by harboring a mixture of biotic elements, where *in situ* diversification processes have occurred in different taxonomic groups. For this reason, it is interesting to evaluate and understand the role of how the Nearctic, the Neotropical and the endemic elements in the region play different roles in the Transmexican Volcanic Belt province.